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INDUSTRIAL RESEARCH

By Frank B. Jewett

Chief Engineer, Western Electric Company, Inc.

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REPRINT AND CIRCULAR SERIES OF THE NATIONAL RESEARCH COUNCIL

NUMBER 4

INDUSTRIAL RESEARCH*

BY FRANK B. JEWETT

CHIEF ENGINEER, WESTERN ELECTRIC COMPANY, INC.

In appearing before a Canadian audience to discuss matters pertaining to the promotion of research and, in particular, to its promotion as related to the industries, I have to confess a lack of that knowledge of conditions in Canada which should be the basis of any constructive consideration of the topic. Fundamentally, the conditions are everywhere much the same but specifically there are great differences which arise in different countries and different parts of the same country because of different educational and industrial needs or because of the different treatment or lack of treatment which the Legislative bodies have accorded. In view of my unfamiliarity with the present situation in Canada, I would ask you to consider what I have to say as being the result of my observations in the United States and of being applicable specifically only to the conditions which now obtain there.

When a man is called upon to testify as to facts or opinions it is, I believe, customary for his testimony to be introduced by a statement of facts intended to establish his right to be heard and have an opinion on the matter in hand. Since the matter before us is at present one in which many diverse views may be held and diverse courses of action advocated, it seems to me proper that this judicial custom should be applied in my own case in order that you may have some basis for deciding upon the weight you may wish to attach to any opinion or suggestions which I may make.

Largely through chance, my training and experience have been such as to give me something more than a dilettante's knowledge of four of the fields which are factors in the problems which we are here to discuss.

* Paper read before The Royal Canadian Institute, Toronto, Canada, February 8, 1919. Reprinted from the *Transactions of the Royal Canadian Institute*, 12, 117-132, 1918.

These fields are those of (a) so called scientific or pure research, most largely exemplified in our universities and higher institutions of learning; (b) engineering; (c) industrial research and (d) general business. Trained as an engineer in a technical school having more or less the standard scholastic ideas of the time as to the proper form of engineering education, chance threw me in the way of spending four years at the University of Chicago in physical, mathematical and chemical research under Prof. A. A. Michelson, one of the world's greatest living physicists—a Nobel prize winner. This novitiate under the tutelage of a master seeker after truth in the realm of physical science completed, I again took up my engineering profession in the form of graduate study and teaching at the Massachusetts Institute of Technology and had no more than completed this work when chance again threw me back into the research field—this time on the industrial side and for what appears to be a life pursuit.

For the past fifteen years I have been intimately associated with the research and engineering activities of the Bell Telephone System, first as the transmission engineer of the American Telephone and Telegraph Company and for the past seven years as assistant chief engineer and chief engineer of the Western Electric Company, Incorporated, which is the research, development and manufacturing part of the Bell System. During this time, which spans nearly the whole of the period of organized industrial research in America, the entire spirit and atmosphere of engineering work in the telephone field has changed from one of inventive experimentation and rule of thumb methods to one in which the principles of scientific research govern practically every course of action. During this period the research laboratories of the System, which were among the earliest to be established in this country, have grown from one or two back rooms in an old building until they now occupy nearly a half million feet of floor space in a building especially designed for their accommodation. At the same time the staff has grown from one or two trained men to one of a number of thousand trained men and women, a large number of whom are graduates of leading research universities and laboratories throughout the world.

Having attempted to qualify, I will now try to give you a picture of the industrial research situation and its problems as I see it.

It needs no statement from me to apprise you of the fact that research and particularly industrial research, is very actively in people's minds and before the public at the present time. Newspapers, magazines and periodicals are continually publishing articles on it; vast numbers of

people are talking, more or less knowingly, about it; and industries and governmental departments, which up to a few years ago had hardly heard of industrial research, are embarking or endeavoring to embark upon the most elaborate research projects. While the conditions which now exist largely through the stimulus of war activities are particularly favorable to a vigorous and healthy growth of both academic and industrial research if properly directed, they are equally favorable to the waste of much human energy and huge sums of money if sanity, clear thinking and a proper sense of proportion in initiative and legislation are neglected.

That much good and enormous advances in the industries of a country will result from a proper application of research methods to their problems cannot be denied by any one who has had experience in this field. It is, I think, equally undeniable, however, that a very grave danger confronts the industries and the nations in some of the misconceptions of what is involved in industrial research which seem to be prevalent throughout the world at the present time. During the past five years there has been so much talk about the wonderful results to be obtained in the application of industrial research, so much exploitation of what Germany was able to do in this line, and so much exploitation of the extent to which the Allied countries have been able to equal and surpass Germany that grave misconceptions have arisen in educational, industrial and governmental circles—misconceptions which if not corrected are sure to cause trouble and bring about a reaction which for a time will tend to drag research down from the high place it should occupy in the realm of human affairs.

The results of the research activities throughout the war have been simply astounding, even to men whose whole training and experience have been along this line. Few, however, realize the exact price paid for these results or appreciate fully the reactions on the orderly peace-time life of the nations brought about by the diversion of our educational and research energies toward the one common purpose of human destruction. With the picture of recent scientific war-time achievements before us, it is difficult to realize that in setting up the machinery to accomplish these achievements we at the same time set up the machinery for the destruction of advances beyond a certain point. By robbing the colleges, universities and industries of their trained scientists and employing them in war's scientific sweat-shop, it was inevitable that stupendous results should be obtained. By so doing, however, we cut off completely the possibility of further advances into the realm of the unknown and like-

wise destroyed our chance of developing new men to carry on the investigational work of the old, when the latter were worn out.

Had the war continued much longer under the conditions which obtained during its maximum violence, it seems clear that it would have resolved itself into a struggle in which mere mechanical ingenuity would have supplanted everything of a really research nature—this because of the fact that while war stimulates very greatly a clever, inventive ingenuity in men it cannot provide the atmosphere nor surroundings which make for developments in the realm of the unknown. During the war I have derived much pleasure from an intimate personal contact with many of the most prominent scientific men of the allied countries and while they were, even to the end, working effectively there was every evidence that the strain was telling and that their productivity could not be long continued. Further, there was no influx of equally good new men.

While I am not in a position to know the exact situation elsewhere in the world, I do know that we in the United States had early in the summer of 1918 arrived at the state where scientific man-producing machinery no longer existed. Practically all of our investigators and those best competent to develop a new generation of investigators were somewhere in the service, but even if many of them had remained in their laboratories there was no human material for them to develop. The young men of college or university calibre not already in the Army or the Navy were in military training camps or schools where they were being crammed with a smattering of the sciences to render them efficient in the handling of the thousand and one details of a modern military establishment.

But despite all these tangible evidences of the alarming decrease in the essential raw human material, projects were being started daily for the establishment of industrial research laboratories in connection with all manner of civilian and military organizations. The common opinion seemed to be that all that was necessary was to construct a building or buildings, put in some machinery and instruments, gather together a few human beings, label the whole a research laboratory and proceed to 'research.'

I venture to say that there are possibly ten times as many so-called research laboratories and more than ten times as many so-called research investigators in the United States today as there were three years ago and yet during that time practically no real research men have been produced. Every day I meet men or groups of men who have acquired a certain superficial knowledge of research matters and a limited vocabulary of its terms and who talk convincingly of the future of industrial

research and of the enormous material benefits to be derived from the extension of this form of activity. They fail utterly to realize that the mere dubbing of a man by some research title does not make him any more a real research investigator than sewing a pair of wings on a tunic makes a man a military aviator. They also fail to realize that even under the most favorable conditions as to human material, the mere getting together of a group of men does not bring a research laboratory into being. Finally, it is clear from the very fact of their being ready to embark upon the project that they do not appreciate that while industrial research, properly organized and carried out with the right kind of human material working in an atmosphere that is sympathetic to industrial research development, has proved enormously valuable, it is under other auspices a sink for money and hopes which is second only to a salted gold mine.

As an ardent advocate and firm believer in the promotion of scientific and industrial research as a means of bettering the condition of our people, I would feel myself derelict in appearing before an audience of this kind if I did not sound a note of warning about the dangers I see and at the same time endeavor to set before you constructively the conclusions which twenty years of active participation in the field of scientific and industrial research have led me to feel are essential to a vigorous and hardy growth of this form of commercial activity.

You will remember that earlier in the paper I mentioned the fact that in fifteen years the scientific research activities of the Bell Telephone System have grown from practically nothing to huge laboratories, with outposts for specific problems in various parts of the United States and even in foreign countries. In addition to being what may be thought an interesting statement of fact, the salient thing to be understood is that the research activities have *grown* and not been formed in any haphazard or over-night fashion. This fact is equally true of every large successful industrial research organization with which I am acquainted. Even today and despite the aggregation of human and material resources which have placed our laboratories in the front rank of industrial research organizations, there are on my list a large number of problems which we are not in a position to undertake. These problems, which are directly and solely in the communication field, are problems of major interest to the industry and are of such a nature that we are absolutely sure they can be solved with positive results of inestimable value to the telephone and telegraph companies and to the public at large, provided only that their solution can be obtained through the application of well organized

industrial research.' Why then do these problems lie essentially untouched? Is it because of a lack of material facilities, of money, of courage to go ahead, or the feeling that these particular researches will not recommend themselves to the business men who are responsible for the commercial destinies of the telephone and telegraph systems? It is none of these. There is no lack of money, no lack of material facilities, no lack of courage, no lack of approval on the part of directors, for we have long ago learned that material facilities are easy to obtain, that money spent in properly directed fundamental research, large though the sums may be, is small in comparison with the direct and indirect returns, and finally that apparent courage in deciding to go ahead is not so very courageous after all when it is exercised by men of ability, training and experience who have shown themselves competent in their own fields, whether these fields be within the laboratories or within the precincts of the executive offices.

What then is it that should stop us from an immediate attack if we are so sure of the ultimate result? The answer is the simple, three-letter word 'men.' Not mere human male bipeds but men endowed by nature with at least a modicum of the spirit of scientific research to which has been added, either through fortune, personal initiative, parental solicitude or a far-sighted policy on the part of the State, that orderly training and opportunity for expansion of intellect without which natural talents are of little avail.

Our case is typical of the situation which confronts every industrial research organization on the continent. The matter of an adequate supply of properly equipped and trained investigators and directors of research is absolutely vital to the growth of industrial research and I am as sure as one can be of anything in the world that all of our visions of the benefits to be derived from a large expansion of industrial research will come to naught if we fail to realize or neglect the fact that in the last analysis we are dependent absolutely upon the mental productivity of men, and men alone, and that we must in consequence provide adequately for a continuous supply of well trained workers.

While there is at the present time some diversity of opinion among the directors of industrial research as to the proper methods to be followed in an industrial research laboratory, there is unanimity on the point that industrial research organizations are essentially man-consuming as distinguished from man-producing agencies. The very fact that they are industrial and commercial in nature means that in the aggregate the performance of industrial research laboratories must be money making

rather than money consuming if they are to continue to exist. For this reason they cannot assemble a staff of investigators to each of whom is given a perfectly free hand with regard to the scope and character of his work. There is unquestionably some ground for debate as to the extent to which it may be desirable to go in permitting or even stimulating individual workers in an industrial research laboratory to undertake the investigation of problems not directly involved in the interests of the company or business of which the laboratory is a part. Personal equation, the relation of any particular laboratory to outside interests and numerous other factors all enter to prevent the formulation of any hard and fast rule in this matter. To me it is self-evident, however, that the great bulk of the work in any industrial research laboratory must be intimately along the lines of the business with which it is associated and must be mainly of a utilitarian character with results measurable by economic standards rather than purely scientific or educational with results measured in terms of increased general knowledge or the production of trained men.

I have said that all of us who have had any considerable experience in this field seem to be a unit as to the necessity for stimulating and maintaining proper sources of supply of our trained workers. There is, however, not the same unanimity with regard to the best method to be employed for bringing about the desired result. At the present time the conditions are sufficiently formative and undeveloped so that many suggestions and schemes can be made. A good many men who have had broad experience in the development of industrial research feel that the best results will in the long run be obtained by fostering a trial of almost any suggestion which is not an obviously foolish one—this on the theory that by so doing we will accumulate rapidly the data and experience from which definite conclusions can be crystallized. Others, and I am one of this number, feel that the information now available is sufficient to permit of drawing certain conclusions and concentrating our efforts on the trial on a large scale of a limited number of experiments in the directions which seem to give most promise of producing the requisite number and kind of trained investigators to meet the increasing needs of industry.

From whatever point we view the problem it seems clear that the agency for producing the trained investigator must be outside and distinct from the industrial research field. It seems reasonably clear also that this agency must be in some way intimately associated with the field of so-called pure scientific research, that is, the form of research intended primarily to extend the bounds of human knowledge as dis-

tinguished from that form of research¹ intended primarily to attain a certain desirable objective through the application of scientific research methods. Two courses only appear promising:

1. The establishment of a limited number of large research laboratories which are endowed either by the State or other private or corporate munificence, or

2. The stimulation of scientific research in a more diverse fashion through the universities and higher educational institutions.

Under the first of these plans the institutions, in addition to their work of extending the bounds of human knowledge through scientific research, would serve as a sort of finishing school for the training of men who have already received a general scientific education elsewhere and who are destined ultimately to engage either in the type of research carried on in such institutions or more largely in the field of industrial research. The success of this plan on a scale adequate to the needs of the State would appear to involve a concentration at the limited number of research institutions of practically all of the country's leading scientists qualified to engage in fundamental research or in the proper instruction of men for the industrial field. This would tend largely to deprive the colleges and universities of the services of all the men with a research trend of mind and leave them with an atmosphere wholly pedagogical in character. Far more serious than the mere absence from the university faculty of the advanced thinkers, would be the fact that such absence would bring about a condition in which there was nothing to stimulate properly qualified young men to take up scientific research as a life pursuit. Also such concentration of fundamental research in a limited number of large endowed institutions would, I think, tend inevitably to diminish rather than increase the wide-spread feeling that the progress of the country was intimately associated with the healthy and vigorous growth of scientific research.

Considerations such as these tend toward an adoption of the second alternative, which is a delegation to the properly qualified universities and institutions of higher education of the duty of training the men who are later to carry on the industrial research of the country. Such a plan does not and should not contemplate making every so-called university or college a center of research. Financial and legislative assistance, of whatever form, should be reserved for those institutions which are equipped or can be equipped with the necessary men and facilities for carrying on properly the work of research and training. In order that the spirit of research and the direct benefits which accrue from it

may become generally known, the institutions which are chosen for carrying on this work should, so far as possible, be located where they can draw from the best elements of the population and where their work will be under the immediate scrutiny of the citizens. While energies should not be scattered through diffuse grants of aid, no stone should be left unturned to stimulate the growth of a research atmosphere in any institution which can by any chance aspire to qualify as a center.

In the United States the direction of efforts tending to promote the progress of fundamental and industrial research and the training of properly qualified men is centering in the National Research Council. This body, which is composed of the leading scientific men of the country from all branches of science and from all of the activities, civil, and military, educational and commercial, was formed in the summer of 1916 by the National Academy of Sciences at the request of the President. Because of the fact that the National Academy of Sciences is the only nationally chartered scientific body and because of the further fact that the President has by proclamation empowered the National Research Council to undertake certain broad duties, it is the agency best qualified to handle the complex problem which is to confront us in the years to come.

During the war the efforts of the National Research Council were, of course, directed to the immediate problems in hand but with the signing of the armistice and the cessation of hostilities broad peace-time plans which had lain dormant were taken up anew, and, with some modifications over the arrangement initially contemplated, the National Research Council is actively at work on plans which bid fair to produce extremely beneficial results. The fact that the Council is composed of the leading men of the country, who are interested in research and the results of its commercial application and who are personally active in the affairs of the Council, makes for the attainment of positive constructive results not otherwise to be hoped for.

Two main problems are at present before the Council. One of these is the organization of the proper means for promoting fundamental research on a high standard of achievement and the correlated problem of training a sufficient number of properly selected men. The other problem is that of promoting the interests of industrial research.

In considering these two activities of the National Research Council it should be understood that the work of the Council is purely in the direction of formulating general policies, correlating and concentrating efforts in any desired direction, and acting as a general clearing house

and advisory body for the multifarious research activities of the country. There is no thought or intention of having the Research Council attempt to undertake or supervise specific research work itself. In the carrying on of its functions as at present proposed, each general activity will be in the hands of a special group whose primary interest is in that particular field. Thus, for example, the group in the National Research Council which is interested in the relations of the Council to engineering and the applications of industrial research to engineering will be, in effect, a group composed principally of and from the great national engineering societies and under the direct supervision of their governing boards.

Both of the alternative schemes noted above for handling the matter of fundamental research and training were carefully considered and at present efforts are being directed along the line which utilizes the existing educational facilities of the country as against the centralized research laboratory idea. This decision does not, of course, mean necessarily the abandonment of the idea of further large fundamental research organizations, such as the Rockefeller Institute, but it does mean that at the present time there is a feeling that such institutions should be looked upon as a means for the attainment of a specific end rather than as part of a nation wide machine.

The plan now actively under consideration and which is of most interest to those engaged in industrial research contemplates the establishment of a number of well-paid research professorships in physics and chemistry in as many of the leading universities as can qualify for the proper carrying on of the work. These professorships, if established, would require that the holder devote the major part of his time to the carrying on or direction of research work and that but a limited part of his time be allotted to teaching. In addition to these research professorships, the plan contemplates the provision of research fellowships in physics and chemistry, to be awarded for a period of years not to exceed five, to men who have shown themselves fitted for such fellowships. As the requirements for fellowship award would tend toward the selection of mature men as distinguished from those but recently graduated, the plan provides for a fellowship emolument sufficiently high so that the recipient, even if married and with a family, would be in a position to accept and devote his entire time to research investigation, save only a limited amount of time which he might be encouraged to devote to the instruction of younger research men.

While it is as yet too early to predict how this plan will finally work out, it seems reasonably certain that the necessary funds for the research

fellowships will be available. The main question appears to be whether the qualified universities will in all cases be able to provide the funds necessary for the research professorships and more particularly with regard to the number of men of research professorship grade who are actually available. There can be little doubt but that the successful working out of some such plan as this would be of very great value to the industries and the cause of industrial research. It would introduce the spirit of research into the universities on a plane far higher than it has hitherto occupied in America and by so doing would react in a stimulative way on the younger men in the university or college—a group from which the future fundamental and industrial research workers must come. The fact that many of the research fellowships would be held by men who had made a mark for themselves in industrial research would make concrete the fact that fundamental research and a doctor of philosophy degree can lead to something other than a pedagogical career, an impression which I am sorry to say has been the prevailing one in America for many years.

That the industries of the United States are more than casually interested in the work which the National Research Council is undertaking is evidenced by the fact that already large sums of money have been contributed by corporations, industries, and individuals toward the carrying on of the work of the Council. For example, to cite a case with which I am personally familiar, the American Telephone and Telegraph Company has recently appropriated \$25,000 a year for a period of five years to be used by the National Research Council in its work of promoting industrial research in the United States and in educating business organizations to the benefits to be derived from it. This is but one of numerous tangible evidences that industries which have eaten of the fruit of a real industrial research department pronounce it good and are desirous of stimulating a further and larger consumption of the same fruit.

It may seem to you that in the foregoing I have gone rather far afield from the subject matter of industrial research and its promotion and application and have emphasized too strongly the fundamental research and training aspects of the problems. My reasons for this have been twofold; first, because there is a very large and rapidly growing appreciation among industrial research workers of the fact that this phase of the matter is of vital importance to them, an appreciation of the fact that if the fundamentals are not properly handled industrial research can have but a limited growth, whereas if the supply of capable trained men is adequate and the field of fundamental research properly cultivated many

of the problems of industrial research itself which now appear difficult of solution will, in a large measure, take care of themselves. In the second place, it seemed to me that as this appreciation is not local to any country or any section, a statement of the present situation in the United States with regard to the methods and plans now under way might be of some interest in Canada. Whether this is so or whether the exact arrangement of any scheme which we south of the border may work out will be applicable to Canadian conditions, I am, of course, in no position to say.

I will not here attempt any long discussion of the best methods for handling industrial research, once a supply of properly trained investigators is assured. There was a time when the proposition of having the colleges, universities and technical schools undertake industrial research on a very large scale was much discussed. Recently such discussion has diminished, largely through a clearer understanding of the requirements for successful industrial research and also, I think, because of a better appreciation of the direction in which the research energies of the universities can be most effectively directed for the advancement of industrial research.

Then too there has been much discussion on the proposition of specialized research organizations maintained by companies or collectively by industries versus large centralized industrial research laboratories, either governmental or private, to which all sorts of industrial research problems can be brought for solution. While I do not know what a study of the conditions in Canada, with its more sparsely settled and less developed industries, might lead me to conclude, I think that in the United States these questions are in a fair way to solve themselves. With us we have a condition of great centralized industries, such as the electrical manufacturing companies, the telephone and telegraph systems, the steel and oil industries and others of the same class, each one of which is of sufficient size to maintain adequately a large and well rounded out research organization competent to handle any of the numerous problems which present themselves. Next, we have a large group of industries, the individual units of which are of considerable size but not sufficiently large to justify the complete research staff which might be needed to cover all of the problems. For this class the tendency seems to be toward an association of the different units for the general support of a research organization available to all of the industries and to which will go all of those problems which are of general interest to the industry as a whole. Finally, there is a great mass of small industries and businesses,

no one of which could hope to maintain a research organization and which are too small and too widely scattered to permit readily of associated efforts such as those just outlined. It is essential, however, that each one of these smaller industries be accorded the advantages which accrue from a proper solution of their problems. It is my feeling that the needs of this industrial class are likely to be met through the establishment of commercial research organizations rather widely distributed over the country and tending at some general degree to a specialization effort. To these organizations the individual industries can bring their problems for solution, much in the same way as they now go to consulting engineers for advice. It is, of course, conceivable that this service might be rendered by a government supported research organization with one or many laboratories. There are large difficulties in such a plan, however, principal among which would be the difficulty of maintaining as high a standard of scientific and technical ability as could be maintained in a non-governmental organization.

But whatever the final solution with regard to the care of the smaller industries, it is absolutely certain that the big industrial units, or the aggregation of units of the second class, will tend to make little or no use of the outside laboratory, be it private or governmental. Their problems are so large and so intimately connected with the intricacies of their business that it is difficult to see how they could have the work carried on by an outside organization without, in effect, making that organization a part of the industry.

In conclusion I should like to present for your consideration a few points which I think are fundamental to the successful carrying out of any broad policy of industrial research growth within a nation and a few other points which my experience has taught me to look upon as beacons in the course of building up an effective and smooth running industrial research organization. The points of the general problem which I would take are:

1. That no extensive and successful industrial research growth can be looked for unless provision is made for a continuing supply of competent men of broad general training and a specific and thorough training in the methods of scientific research.
2. That coincident with the growth of real industrial research there must be a corresponding and equal growth and development in the domain of fundamental scientific research which will broaden the bounds of knowledge and open up new avenues for the industrial research worker.

3. That there must be education to develop a full understanding of the material and economic advantages which will result from the supplanting of the purely cut and try inventive type of growth by the application of scientific research methods and the further knowledge that a vigorous and healthy growth of fundamental scientific research is an integral and absolutely necessary part of the problem. In the one case this education must be directed toward the industrial interests for the purpose of indicating to them the advantages to be gained by an abandonment of methods which are not in accord with the present day state of world knowledge and the building up of a demand for the right type of men, and in the other case toward the population at large for the purpose of instilling an appreciation of the advantages which will accrue to the nation and attracting to the field of research, whether fundamental or industrial, a larger proportion of qualified men; also for the purpose of having the people at large view with sympathy a reasonable allotment of general funds for the advancement of research activities.

4. That a realization of all of the foregoing can best be obtained by a close coöperation between the industrial and business interests of the country and the higher educational institutions, which are already looked upon with favor by educated and thinking people, and from which must come the men qualified to build up industrial research.

5. That whatever the scheme finally adopted to provide for an expansion in the domain of fundamental research and the development of competent industrial research workers, care must be taken to insure that pressure from the industries will never be so great as to withdraw those men who can render the greatest service by continuing as investigators in the field of pure research and the training of younger men. Such a course would be suicidal if long continued and I mention the point because of the fact that my experience indicates a considerable tendency on the part of industries who have benefited from industrial research to endeavor to attract into their service the best of the university research men. I confess that the temptation to do this is very great and that the monetary inducements which industry can offer to the individual are large and not easily to be withstood by a man whose normal human reaction is for the material welfare of his family.

Finally, as to those specific points which may be of interest to anyone endeavoring to build up an industrial organization,

1. The research department must be so organized, developed and equipped with men and machinery that the net result, direct or indirect, will be of decided monetary value to the industry. Otherwise, it has no reason to be.

2. The present state of the art is such that a large number of the problems falling within the field of the industrial research laboratory are inherently expensive. For this reason, while enormous returns may be possible from the successful completion of any line of research, lack of success or an attempt to conduct it with inefficient help will mean the waste of much valuable time and money. For these reasons the choice of the staff and the careful consideration of all of the factors in any problem are of the utmost importance.

3. That successful industrial research under modern conditions is essentially one of organization and group working, as distinguished from the essentially individualistic work of fundamental research. For this reason extreme care must be taken to secure competent executives, either from the ranks of those whose primary training has been along research lines and who have shown capacity for handling men and complicated problems or from those of executive capacity and experience who have shown a proper sympathy for the requirements of research.

4. That all industry tends to be conservative and that great care must be taken not to attempt the forced growth of a broad industrial research development where a too rapid growth will engender the active opposition of those who have been educated in a different environment. My experience has indicated that there is never any trouble where the proper method is employed but that there is always trouble if the so-called practical man feels that the proposed new methods are essentially a reflection on his ability and that his point of view is not receiving sufficient consideration. As a matter of fact, the practical man's point of view and his knowledge, gained by long experience, will be found to be one of the chief assets of the successful industrial research worker.

5. That some industries are much more conservative in their attitude toward the adoption of modern research methods than others. In general, I think it will be found that the most conservative are the oldest and are those industries which existed long before the science of their art had been developed. Because of the fact that modern electrical and chemical industries have grown directly from pure scientific developments, I think they will be found to be easier fields for the cultivation of industrial research than older industries, such as those which were well developed in the earlier periods of human affairs.

6. Finally, a most important point, not to be lost sight of in the organization of a successful industrial research department, is the fact that many very capable men trained for industrial research are essentially devoid of certain commercial attributes. Many of them, for instance,

fail to realize that on a large number of their problems time is an essential element in the work, while others fail to give due weight to that phase of the work which lies between the completion of the research activity and the introduction of the results into commercial manufacture or employment under modern conditions where the day by day control must, of necessity, be largely in the hands of those who are not highly trained skilled workers. For this reason it is essential that whoever is responsible for the direction and success of the industrial research undertaking should be a man with a broad outlook, a full appreciation of all of the factors of the business problem and a man who can sympathize with and appreciate the varying points of view which he encounters and who can harmonize all of the activities into a smoothly-working machine.

In closing I wish merely to go on record with you by saying that after many years of experience, I now, as an executive in a large technical organization, am more than ever a firm believer in the benefits to be derived from a vigorous stimulation of both fundamental and industrial research, benefits which I believe will accrue not only to individual industries but to the people at large as well. It seems to me that, provided we have proper legislation to safeguard a just distribution of the benefits, we have in industrial research a most valuable means for ameliorating and bettering the conditions of mankind.



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